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THE USE OF FERTILIZERS IN ALBERTA

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This circular is prepared with the idea of bringing together in brief form information dealing with the nature of fertilizers, the results obtained from their use, and answers to some of the questions which are raised by the farmer. It is by no means a complete discussion of the important question of fertilizers, but it is hoped that it will fill a long felt need, and aid the farmer in understanding the primary principles of the fertilizer question.

A productive soil is the pride of any good farmer. He knows its productivity by the crops it produces, but the chemical elements needed in deficient soils is a problem for the soil scientist.

Fertile soils are fundamental in the maintenance of agriculture. The fertility of soils is not inexhaustible under all cultural and cropping conditions. Plants and crops possess the ability to collect and assemble plant foods from the soil in forms which are suitable for the food of man and animals. Every crop removes part of the original fertility from the soil, and since nature does not provide plants with a balanced ration the farmer must, (1) practice good cultural methods, (2) make the best use of rotations using legumes where possible, (3) make the best use of his farm manure, and (4) add plant food elements as fertilizers where required.

The history of the development of agriculture shows that the use of fertilizers is an important function in the maintainance of highly productive soils. When virgin soils are first cultivated they are in a relatively high state of productivity, but with continuous cultivation and cropping the time comes when there is a scarcity of one or more of the essential plant food elements in sufficiently available quantities to meet the requirements of maximum crops. It is then that deficiencies in plant food elements must be supplied by fertilizers. Most people think of fertilizers as the product especially manufactured for this purpose. In general this is correct, but the term fertilizer can properly be applied to products of the farm which are available at no cost to the farmer.

Fertilizers

A fertilizer is any material that supplies one or more plant food elements such as nitrogen, phosphorus, potassium, sulphur, calcium, etc., that is used to enrich soils. Thus farm manure, green manure, legumes and commercial fertilizers all fall within this definition.

Farm Manures.

The fertilizers a farmer has on his own land include barnyard manure, green manure and clovers. The farmer cannot produce sufficient farmyard manure from his own farm to meet his fertilizer requirements. He should use manure in such a way that it will be spread over as large an area as possible. This will give greater immediate returns per ton than if it is spread at heavy rates. For example, it is better to spread at the rate of 10 tons per acre than at the rate of 30 tons per acre except for high priced crops. Manure is not in itself a well balanced fertilizer, since it is relatively low in phosphorus. Light applications of manure should be supplemented with some phosphate fertilizer.

Green Manures and Clovers.

Green manures and clovers when used as fertilizers are valuable since they add active organic matter to the soil. With the exception of clovers, which have the power to utilize atmospheric nitrogen when properly inoculated, they do not add any mineral which had not been previously obtained by them from the soil. If they are removed from the soil in the form of hay they may actually be soil depleting rather than soil improving crops.

Commercial Fertilizers.

Commercial fertilizers are products manufactured and sold for the purpose of supplying plant food elements. These products may contain one or more plant food element. Generally the plant food elements supplied by fertilizers are present in readily available forms. Fertilizers containing one or more of the following: nitrogen, phosphorus, and potassium, are sold according to specifications as provided in the Dominion Fertilizer Act, which requires that sales be made according to guaranteed analysis. The Act requires that the guaranteed analysis be provided in a conspicuous place on the outside of the container.

Guaranteed Analysis

The guaranteed analysis as shown on the outside of the container is always expressed in the following order: Nitrogen first, phosphoric acid second, potash third. Thus a fertilizer labelled 4-10-10 would contain 4% of nitrogen (N), 10% of phosphoric acid (P_2O_5) and 10% of potash (K_2O).

Some of the fertilizers most common on the market in Alberta are:

	N	P_2O_5	K_2O	Total
Triple superphosphate	0	43	0	43
Ammonium phosphate	11	48	0	59
Ammonium phosphate	16	20	0	36
Ammoniated superphosphate	2	19	0	21
Ammonium sulphate	20	0	0	20
Complete	4	10	10	24
Complete	9	27	9	45

Some of the fertilizers are concentrated and contain high quantities of the plant food combinations, such as ammonium phosphate 11-48-0, which contains a total of 59% of nitrogen (N) and phosphoric acid (P_2O_5), whereas other of the fertilizers are less concentrated and contain lower quantities of the plant food combinations, such as 2-19-0 which contains a total of 21% of nitrogen (N) and phosphoric acid (P_2O_5). Fertilizers should be sold roughly proportional to the plant food content and when the farmer sees the analysis on the container he is in a position to figure for himself what he is getting for his money. If the farmer needs only phosphate he can purchase this most cheaply in a concentrated fertilizer which carries only phosphorus, likewise if he needs only nitrogen he can purchase this in a fertilizer which does not also contain phosphorus or potassium.

If the individual plant food elements are valued according to their lowest cost per unit (basis 1938-1939 prices with all discounts) then we might assume the approximate following values for the plant food elements in fertilizers:

Nitrogen (N)	9 cents per pound
Phosphoric acid (P_2O_5)	5.5 " " "
Potash (K_2O)	5.6 " " "

For each one per cent. guarantee of nitrogen (N), or phosphoric acid (P_2O_5), or potash (K_2O) the fertilizer would contain one unit (or 20 pounds) per ton and the following values are indicated:

For example, a fertilizer containing guaranteed analysis of 1% each of nitrogen (N), phosphoric acid (P_2O_5) and potash (K_2O) shows the following values:

Nitrogen (N)	1%—20 lbs.×9c per lb.—	$1.80 per ton
Phosphoris acid (P_2O_5)	1%—20 lbs.×5.5c per lb.—	1.10 per ton
Potash (K_2O)	1%—20 lbs.×5.6c per lb.—	1.12 per ton
Or a total value of		—$4.02 per ton

The above prices would approximate the actual costs only when the nitrogen (N) was purchased as ammonium sulphate, the phosphoric acid (P_2O_5) as triple superphosphate, and the

potash (K_2O) as the muriate or sulphate of potash. This does not mean that the farmer can purchase the plant food elements in all fertilizers at the above prices.

Table I shows the relationship between the estimated plant food values (basis (N) 9 cents, (P_2O_5) 5.5 cents, and (K_2O) 5.6 cents per lb.) and the actual cost per ton of the common fertilizers on the market in Alberta.

Table 1.—Guaranteed analysis, estimated plant food value and actual cost (1938-39 prices) of some fertilizers sold in Alberta.

	Guaranteed analysis %			Plant food per ton pounds			Plant food value per ton			Total value per ton	Lowest market cost per ton car lots*
	N	P_2O_5	K_2O	N	P	K	N	P	K		
Triple superphosphate	0	43	0	.....	364	.....	.....	$47.50	.....	$47.50	$47.50
Ammonium phosphate	11	48	0	220	406	.....	$19.80	52.80	.....	72.60	58.50
Ammonium phosphate	16	20	0	320	169	.....	28.80	22.00	.....	50.80	46.50
Ammoniated superphosphate	2	19	0	40	161	.....	3.60	20.90	.....	24.50	33.50
Superphosphate	0	18	0	.....	152	.....	.....	19.80	.....	19.80	33.50
Ammonium sulphate	20	0	0	400	.....	.....	36.50	.....	.....	36.50	36.50
Muriate of potash	0	0	52	.....	.....	860	.....	.....	$56.00	56.00	56.00(1)
Sulphate of potash	0	0	48	.....	.....	797	.....	.....	53.76	53.76	66.50(1)
Complete (mixed)	9	27	9	180	228	149	16.20	29.70	10.08	55.98	53.50(1)
Complete (mixed)	4	10	10	80	85	166	7.20	11.00	11.20	29.40	43.50(1)
Complete (mixed)	2	16	6	40	135	100	3.60	17.60	6.72	27.92	44.50(1)
Sodium nitrate	15	0	0	300	.....	.....	27.00	.....	.....	27.00	55.00(1)
Farm manure	.5	.25	.5	10	2	8	.90	.28	.56	1.74	

*The cost prices as shown in this column (1938-39 prices) are for early orders, in car lots, cash payment, and delivery off cars. These represent the cheapest cost possible to the farmer and include freight charges applied to the greater part of the present cultivated area in Alberta. Charges for the Peace River district are $2.50 per ton more than the above prices, due to extra freight charges. The purchaser of low grade fertilizers must pay extra freight charges for each unit of plant food.

(1) These fertilizers are seldom purchased by prairie farmers, and therefore the prices listed do not have off car discounts.

From this table it may be calculated that 1 pound of nitrogen costs about 9 cents in ammonium sulphate and about 18 cents in sodium nitrate. One pound of phosphorus costs about 13 cents in 43% triple superphosphate and about 22 cents in 18% superphosphate.

Other Fertilizers

Other fertilizers which are in less common use in Alberta are mentioned in the following list:

	N	P_2O_5	K_2O
Tankage	6	10	0
Bone meal	2 to 6	18 to 25	0
Wood ashes	0	2	5

These fertilizers are not commonly used for the grain and hay crops. The first two are in demand for greenhouse and

garden use. Wood ashes contain about one-third lime, but are low in potash and phosphorus. This product can be used at the rate of from 1 to 2 tons per acre in cases where the soil is distinctly acid or where it is in need of potash.

Soil Amendments

Some materials are used chiefly to improve soil conditions and may or may not be fertilizers. In this group would be:

Lime.

Used for the correcting of soil acidity. This might also supply calcium as a plant food element. In this class is also marl, a natural product found in certain areas. Marl is an earthy material containing variable amounts of calcium carbonate. Wood ashes could be used in place of either lime or marl. Where these substances are required it is desirable to apply at the rate of 1 to 2 tons per acre. Such application is generally adequate for three or four years. However, in most cases, Alberta soils do not require the addition of these materials. In most cases where alfalfa or sweet clover grow well there is no need for lime.

Gypsum and Other Sulphur Materials.

Gypsum (calcium sulphate) and the other substances mentioned below will not correct soil acidity but, under certain conditions such as for clovers on the wooded soils, would supply sulphur as a plant food. Other sulphur containing compound such as sodium sulphate or even sulphur would likewise meet a sulphur deficiency in soils and would be beneficial for clovers, but would not necessarily be adequate for the grasses or grain crops. For grains, grasses, or mixtures of grasses and clovers, fertilizers such as ammonium sulphate or ammonium phosphate (16-20), containing nitrogen as well as sulphur, have given the best results on the gray soils, but for clovers, alfalfa, and other legumes, properly inoculated with nitrogen-fixing bacteria, gypsum, sodium sulphate, or flowers of sulphur may be expected to produce similar results.

Most of the black and brown prairie soils are adequately supplied with sulphur.

Peat.

A fairly heavy application of peat, plowed down, will improve the physical condition and moisture holding capacity of gray wooded and clay soils, because these soils are frequently deficient in organic matter. Such applications may be made to garden soils and other limited areas. Peat lands are frequently found within the gray wooded soil areas.

Well decomposed peat was found to be more beneficial than coarse, light colored peat.

Fertilizer Trials

Extensive fertilizer trials were first conducted throughout Alberta during the years of 1928, 1929 and 1930. The organizations co-operating in these trials in 1930 were the Provincial Department of Agriculture, Dominion Experimental Farms, University of Alberta, Department of Interior Irrigation Experiment Station, Consolidated Mining and Smelting Company, C.P.R., Massey Harris Company, Cockshutt Plow Company, John Deere Plow Company, General Motors, and 447 farmer co-operators. The trials extended from the southern part of the province to the Peace River country and included such crops as wheat, oats, barley, and sugar beets. The results of the 1930 trials were published by the Provincial Department of Agriculture.

Only two fertilizers were used in the majority of these trials and the fertilizers were each applied at two rates. The results of these trials are summarized in Table 2.

Table 2.—Average increases (bus. per acre) for fertilizer trials with grains, 1930.

Crop	No. of Trials	Triple superphosphate		Ammonium phosphate 11-48	
		50 lbs.	100 lbs.	43 lbs.	86 lbs.
Wheat on fallow	118	6.1	6.8	6.4	7.8
Wheat on spring plowing	40	3.2	4.0	3.6	4.6
Wheat on fall plowing	14	3.2	4.2	3.1	4.6
Wheat on stubble land	16	3.1	3.1	3.2	4.1
Wheat on breaking	5	2.9	3.1	3.8	4.6
Average of 75 trials (all except fallow)	.....	3.1	3.8	3.4	4.5
Oats on fallow	11	11.2	13.6	11.5	14.1
Oats on fall plowing	9	13.2	10.2	11.5	10.5
Oats on spring plowing	36	8.0	10.0	8.8	10.3
Oats on stubble land	12	8.5	9.4	9.0	7.8
Oats on breaking	4	8.1	8.2	7.7	10.9
Average of 61 trials (all except fallow)	.....	8.9	9.6	7.6	9.9
Barley on spring plowing	6	3.5	7.5	3.3	4.8
Barley on fall plowing	3	5.0	10.1	8.7	9.7

The results from the 1930 trials show:

(1) Increases were greater on fallow than where the land was less well prepared.

(2) Slightly greater yields were obtained from ammonium phosphate (11-48) than from triple superphosphate.

(3) The yields were slightly greater for the heavier applications, but the use of the heavy rates was not as economical as when the rates were from 40 to 50 pounds per acre.

(4) Increases for sugar beets varied from 2 to 7 tons per acre with a definite improvement in the quality. Fertilizers were applied at approximately 100 and 200 pound rates.

(5) In 80 per cent. of the cases the grain increases were greater than 2.5 bushels per acre. Most of these trials were conducted on the brown and black soils, and show very definite results from phosphate fertilizers.

University Experiments

The first field trials with commercial fertilizers were started in 1921 on the University farm. Extensive field trials have been conducted on both the black soils and gray wooded soils since 1928.

The Soils Department experimental field at Edmonton is on black soil. This field was not cultivated before 1923, when it was broken and seeded to grain. Grain was grown from 1923 to 1930, without fertilizers, in order to determine the variability of the plots. Since 1930, a rotation of crops has been followed, consisting of two years of clover and three years of grain, and fertilizers have been applied each year.

The Soils Department experimental field at Breton is on gray wooded soil. This field was broken several years before the fertilizer experiments were started in 1929. Since 1930, a rotation consisting of clovers and grains has been followed, and fertilizers have been applied each year. On part of the field only wheat has been grown.

Numerous fertilizer experiments in co-operation with farmers have also been conducted since 1928 on both black soils and gray wooded soils. The results from the Soils Department experimental fields and farmer co-operative trials are summarized in Table 3 for grains, and Table 4 for hays.

Grains

The average increases for grains for the ten years (1929-1938) for five different fertilizers are given in Table 3.

Black Soils.

It will be seen that the best results with grains on the black soils (Edmonton adjacent districts) were obtained from triple superphosphate and ammonium phosphate (11-48). The average increases from these two fertilizers were 7.1 and 6.3 bushels of wheat respectively. Increases of 2.1 and 2.9 bushels of wheat were obtained from single superphosphate and ammonium phosphate (16-20) respectively. In these trials on

the black soils the low analysis fertilizers were less effective, pound for pound, than were the more concentrated fertilizers. Ammonium sulphate did not pay its cost for grains on these soils.

Table 3.—Average annual increases of grain for fertilizer treatments on black soils and gray wooded soils (bushels per acre)—1929-1938.

BLACK SOILS

Crop	Ammonium phosphate 11-48	Triple super-phosphate	Single super-phosphate	Ammonium phosphate 16-20	Ammonium sulphate
Wheat	6.3	7.1	2.1	2.9	0.7
No. of trials	54	63	9	4	30
Oats	5.4	5.4	—1.6	8.3	—0.7
No. of trials	23	27	2	4	14
Barley	7.5	4.0	0.5	5.0	1.5
No. of trials	17	14	2	2	11
Total No. of trials	94	104	13	10	55

GRAY WOODED SOILS

Wheat	4.8	2.7	2.6	8.0	8.5
No. of trials	18	30	3	34	34
Oats	6.5	3.9	—1.0	10.3	16.2
No. of trials	12	18	4	16	16
Barley	7.1	2.5	3.7	10.0	10.1
No. of trials	4	14	10	22	21
Total No. of trials	34	62	17	72	71

Average value of annual increase per acre for fertilizer when wheat is 60 cents, oats 26 cents, and barley 42 cents.*

BLACK SOILS

Wheat	$3.78	$4.26	$1.26	$1.74	$ .42
Oats	1.40	1.40	—0.42	2.16	—0.18
Barley	3.15	1.68	0.21	2.10	0.63

GRAY WOODED SOILS

Wheat	2.88	1.62	1.56	4.80	5.10
Oats	1.69	1.01	—0.26	2.68	4.21
Barley	2.98	1.05	1.55	4.20	4.24

*The annual cost of the fertilizers varies from about $1.00 to $1.25 per acre. This would have to be subtracted from the above figures in order to obtain net returns.

Gray Wooded Soils.

It is quite a different story with the grains on the gray wooded soils. Here the fertilizers high in nitrogen are most effective. Thus the greatest increases were obtained from ammonium sulphate and ammonium phosphate (16-20), with ammonium phosphate (11-48) next, but definitely better than triple superphosphate or single superphosphate. The average increases for ammonium sulphate were wheat 8.5 bushels, oats 16.2 bushels, barley 10.1 bushels; for ammonium phosphate (16-20) the average increases were wheat 8 bushels, oats 10.3 bushels, and barley 10 bushels. Increase for ammonium phosphate (11-48) were about 60% of the above figures, while the increases for the single superphosphate and the triple superphosphate were roughly one-third as great as for the best fertilizers. These experiments indicate that such fertilizers as triple superphosphate, single superphosphate and ammonium phosphate (11-48) should not be used for grains or grasses on the gray wooded soils, but that ammonium sulphate and ammonium phosphate (16-20) are very effective and give good returns.

Hays

The average increases for hays for the ten years (1929-1938) for seven different fertilizers are given in Table 4.

Black Soils.

The responses for fertilizers applied to the black soils were less definite for hays than for grains. The ammonium

Table 4.—Increases for fertilizers on black soils and gray wooded soils. Pounds of hay per acre. Average of all clovers, grasses, mixtures and green feed (129-1938).

BLACK SOILS

	Ammonium phosphate 11-48	Triple superphosphate	Single superphosphate	Ammonium phosphate 16-20	Ammonium sulphate	Gypsum	Sodium sulphate
Av. increase per acre	488	400	....	1040	256	....	....
No. of trials	53	51	....	12	36	....	....
No. of decreases	8	7	....	0	9	....	....
No. of increases 300 pounds or less	9	7	....	0	8	....	....

GRAY WOODED SOILS

Av. increase per acre	930	756	1480	2291	2256	1444	963
No. of trials	25	64	29	97	92	30	22
No. of decreases	0	5	3	0	2	2	3
No. of increases 300 pounds or less	1	8	1	2	4	1	3

phosphate (16-20) was the only fertilizer that has consistently given definite increases. With the other fertilizers from 25 to 50 per cent. of the trials showed but very small responses.

Gray Wooded Soils.

All fertilizers gave, in general, definite responses when applied to hays. From 75 to 95 per cent. of the trials showed decided increases. The greatest responses were from ammonium sulphate and ammonium phosphate (16-20). These were likewise the best fertilizers for the grain. Any fertilizer containing sulphur gave good results when applied to clovers, but nitrogen was necessary for the grasses. Thus gypsum (18% sulphur), sodium sulphate (dry 22% sulphur, hydrated 11%), single superphosphate (9% sulphur) gave increases from ½ to ¾ tons of hay (containing clovers), whereas ammonium sulphate (24% sulphur) and ammonium phosphate (16-20) (14% sulphur) gave over 1 ton increases.

University Experimental Farm, Edmonton

The average increases (1931-1938) of wheat, oats, barley, and clovers for four different fertilizers applied annually to the rotation on the Soils Experimental Farm at the University are shown in Table 5. The soil was first broken in 1923, cropped without fertilizers until 1931, and fertilized since 1931. The rotation is two years clover and three years grain, and consists of five series so that each crop is grown each year. The check plots are replicated six times and each fertilizer is replicated three times.

Table 5.—Crop increases for fertilizers on black soil (1931-1938) Soils Experimental Farm, Edmonton.

Fertilizer	Bushels per acre			Pounds per acre
	Wheat	Oats	Barley	Clovers
Ammonium sulphate	0.5	—2.9	0.7	000
Triple superphosphate	4.5	4.4	2.7	124
Ammonium phosphate 11-48	4.7	—1.0	4.6	130
Complete (Amm. phos. 11-48—potash)	6.6	6.7	4.1	187

The initial fertility of the soil is high as indicated by average wheat yields of 28.1 bushels for the check plots. Extremely poor and extremely good crop years occurred in the (1931-1938) period. In 1937 there was a crop failure, the yields from the checks being 6 bushels with no increase for the fertilizers, whereas in 1933 the checks yielded 46 bushels and the phosphated plots 51 bushels per acre.

Ammonium sulphate was of no value in these experiments. The plots receiving phosphorus as triple superphosphate, am-

monium phosphate (11-48) or as complete gave substantial increases. Compare increases of about 5 bushels of wheat in these experiments with increases of 6 to 7 bushels in the experiment previously discussed.

The average increases for hays on the Soils Experimental farm at Edmonton (see Table 5) are small and not economical. It should be mentioned, however, that for two of the eight years the hays showed satisfactory increases.

University Experimental Farm, Breton

The Breton experimental plots are located on typical wooded soil about two miles south and east of the town of Breton. The regular rotation contains four series: wheat, oats, barley in which clovers are nursed, and the clovers consisting of a mixture of sweet and Altaswede clovers. In addition there is a series on which wheat is grown continuously, and one for alfalfa or clovers. The above rotation has at present gone through two complete rotations of four years each in which the clovers have occupied the land for only one year in each rotation. The plots in the above series are treated with different fertilizers. Each series consists of 11 plots in the main section treated as follows:

Plot 1. Check.
Plot 2. Manure applied once every three years at the rate of 22 tons per acre per application.
Plot 3. Complete fertilizer consisting of 60 lbs. of ammonium phosphate (16-20) and 30 lbs. of potassium sulphate per acre each year.
Plot 4. Ammonium sulphate, 60 lbs. per acre each year.
Plot 5. Check.
Plot 6. Lime (marl) applied once every four years at the rate of 1 ton per acre.
Plot 7. Lime and phosphorus. Lime applied as on plot 6 and phosphorus as triple superphosphate at the rate of 50 lbs. per acre each year.
Plot 8. Phosphorus, triple superphosphate, 60 lbs. per acre each year.
Plot 9. Manure and phosphorus. See application for plots 2 and 8.
Plot 10. Ammonium phosphate (16-20), 60 lbs. per acre each year.
Plot 11. Check.

The experimental field had been cropped prior to the experiments for at least ten years, and had reached a stage where the crop yields were decidedly unsatisfactory. It was laid down to plots and some fertilizers applied in 1929. The major part of the treatment was applied in 1930, and the remainder in 1931.

The yields and increases from the Breton experimental plots for the year 1930 to 1938 are reported in Table 6.

The grain yields reported in Table 6 show results for wheat grown continuously, wheat after fallow and wheat as the first

crop after clover, oats as the second crop after clover, barley as the third crop after clover, and clovers. This table also contains the increases of grain reported as bushels per acre, and hay as pounds per acre, for the various fertilizers.

It is apparent from the yield data in Table 6 that certain of the fertilizers when applied to the crops in the rotation have been entirely satisfactory as shown by average yields of wheat of from about 28 to 34 bushels, average yields of oats from about 44 to 55 bushels, average yields of about 21 to 22 bushels of barley and average hay yields from 1¾ to 2½ tons. These yields are approximately double the yields from the check plots, even where clover has been grown but where no fertilizers have been applied. (See Figs. 1 and 2.)

Table 6.—Crop yields and increases for fertilizers on gray wooded soils at Breton (1930-1938)

Average yields per acre

Treatment	Wheat continuous 7 crops in 9 years	Wheat after fallow, 2 crops in 4 years	Rotation			
			Wheat after clover, 7 crops	Oats after wheat after clovers, 8 crops	Barley after oats after wheat after clovers, 9 crops	Clovers, 8 crops
Checks	11.2	19.2	14.2	29.8	13.0	1394
Lime	11.6	19.2	18.4	33.8	15.1	2376
Triple superphosphate	10.6	17.9	20.3	35.6	14.4	3028
Lime, triple superphosphate	12.4	22.8	23.3	39.9	16.3	3429
Manure	12.9	24.0	22.9	42.4	19.0	2552
Manure, triple superphosphate	14.1	26.1	28.5	44.2	22.1	3622
Ammonium sulphate	15.7	27.7	27.9	55.3	22.4	4719
Ammonium phosphate (16-20)	14.4	26.2	30.3	47.6	20.5	4544
Complete (amm. phos. 16-20+potash)	16.8	29.7	34.1	49.8	21.4	5023

Average increases for fertilizers per acre

Lime	0.4	0.0	4.2	4.0	2.1	982
Triple superphosphate	—0.6	—1.3	6.1	5.8	1.4	1634
Lime, triple superphosphate	1.2	3.6	9.1	10.1	3.3	2035
Manure	1.7	4.8	8.7	12.6	6.0	1158
Manure, triple superphosphate	2.9	6.9	14.2	14.4	9.1	2228
Ammonium sulphate	4.5	8.7	13.7	25.5	9.4	3325
Ammonium phosphate (16-20)	3.2	7.0	16.1	17.8	7.5	3150
Complete (amm. phos. 16-20+potash)	5.6	10.5	19.9	20.0	8.4	3629

For the wheat it will be seen that (compare first three columns of the last four lines, Table 6) when fertilizers were applied to the continuous wheat the increases varied from 2.9 to 5.6 bushels, when these same fertilizers were applied to

wheat after fallow the increases varied from 6.9 to 10.5 bushels, whereas the increases for wheat after clover varied from 13.7 to 19.9 bushels per acre. This shows that the fertilizers gave from three to four times as much increase for wheat when they were applied to wheat after clover as when they were applied to wheat grown continuously. These same four fertilizers, namely manure and triple superphosphate, ammonium sulphate, ammonium phosphate (16-20), and complete

Fig. 1.—Reward wheat (first crop after clovers) grown on wooded soil at Breton, 1933. The average yield (1930-1938) of the unfertilized plot on the right was 14.2 bus.; and the plot on the left, fertilized with ammonium phosphate (16-20) was 30.3 bus.

Fig. 2.—Clovers (sweet and Altaswede) grown at Breton. Check plot on left yielded 1,394 lbs. of hay. Plot on right, fertilized with ammonium sulphate, yielded 4,719 lbs. of hay.

likewise gave the greatest increases for oats, barley and the clovers. The ammonium sulphate was slightly superior to ammonium phosphate (16-20) with the exception of the first grain crop following the clovers. Both of these fertilizers, in general, gave increases almost as great as those from the complete fertilizer, and the increases were obtained at a lower cost per acre.

The significance of the increases for fertilizers is shown in another manner in Table 7, where the values of the crop increases are expressed as dollars. This table contains the costs of the various fertilizers for a period of 4 years and the net values of the crop increases after deducting fertilizer costs. A comparison is shown between the cropping systems where wheat is grown continuously, and where wheat, oats, barley and clovers are grown in rotation. Two price levels for crops are used: low prices where wheat is 60 cents, oats 26 cents, barley 42 cents, hay $5.00; and high prices where wheat is 70 cents, oats 30 cents, barley 50 cents and hay $8.00. The annual net returns per acre may be obtained by dividing the figures given in the table by four.

From Table 7 it will be seen that the greatest net return where wheat was grown continuously was obtained from am-

Table 7.—Net returns per acre (for 4 years) for continuous wheat and for crops in rotation on gray wooded soils at Breton. Low prices, wheat 60 cents, oats 26 cents, barley 42 cents, hay $5.00. High prices, wheat 70 cents, oats 30 cents, barley 50 cents, hay $8.00.

Fertilizers†	Continuous wheat 3 crops in 4 years			Rotation 4 crops in 4 years		
	Cost of fertilizers	Net returns for 4 years		Net returns for 4 years		Cost of fertilizers
		At low prices	At high prices	At high prices	At low prices	
Lime*	.....	$ .72	$ .84	$ 9.12	$ 6.89	.....
Triple superphosphate	$3.57	—4.65	—4.83	8.48	5.09	$ 4.76
Lime*, triple superphosphate	3.57	—1.41	—1.05	14.43	9.81	4.76
Manure*	.....	3.06	3.57	17.50	13.92	.....
Manure*, triple superphosphate	3.57	1.65	2.52	22.96	16.91	4.76
Ammonium sulphate	3.30	4.80	6.15	30.84	22.71	4.40
Ammonium phosphate (16-20)	4.20	1.56	2.52	27.36	10.72	5.60
Complete (amm. phos. 16-20, potash)	7.20	2.88	4.56	29.04	20.16	9.60

†Triple superphosphate, 50 lbs. per acre cost $1.19 per year.
Ammonium sulphate, 60 lbs. per acre cost $1.10 per year.
Ammonium phosphate (16-20), 60 lbs. per acre cost $1.40 per year.
Complete (amm. phos. 16-20 60 lbs. plus potash 30 lbs.) per acre cost $2.40 per year.

*No cost has been allowed for manure or lime. The farmer will use what manure he has on his own farm at no cash outlay. Pay for his labor in spreading it will be determined by the crop increase obtained. He can not afford to buy lime from the builder at $20.00 to $30.00 per ton and will use this material only when a supply of marl is near and the only cost involved is the time required to spread it.

monium sulphate, $4.80 (low prices) for 4 years or $1.20 per year per acre; whereas this same fertilizer also gave the greatest net return for the rotation. With the rotation the net return per acre for 4 years was $22.71 or $5.68 per year. Very good net returns were also obtained from ammonium phosphate (16-20) and for the complete fertilizer. Manure and phosphate was a good combination.

Summary of Results from Breton Field

Continuous Grain.

On the continuous wheat series the yields were unsatisfactory and in no case exceeded 17 bushels per acre. The increases for the better fertilizers varied from approximately 3 to 6 bushels, but some of the other fertilizers failed to pay their costs when applied to continuous wheat.

Grain after Fallow.

The yields of wheat and also the increases from fertilizers were greater after fallow than with continuous wheat, but less than in the rotation which included clover.

Rotation Including Clover.

The most important fact shown by these experiments is the great benefit of clovers combined with the proper fertilizers for the gray wooded soils. The average yield of wheat for the best fertilizer was approximately 34 bushels, and the increases for the better fertilizers varied from approximately 14 to 20 bushels. All fertilizers gave definite increases when clovers were grown, but lime would not be economical if it had to be purchased at high prices. As shown in Table 7, the most economical fertilizer used on the Breton field was ammonium sulphate, but the ammonium phosphate (16-20) and the complete fertilizer (2 parts ammonium phosphate (16-20) and 1 part potassium sulphate) have also given very satisfactory returns.

The practice of growing legumes and using fertilizers implies that sufficient livestock must be kept to ensure a home market for the extra hay.

Fertilizers Required for Alberta

On prairie soils of the grassland and park belt areas phosphorus is the first essential and nitrogen is of secondary importance. For the gray wooded soils nitrogen is generally of first importance, especially for grains and grasses, whereas for the clovers sulphur is of first importance but nitrogen may be of some value.

Fertilizers will give best results when combined with good farming practice, but cannot take the place of good farming.

In all cases where the use of commercial fertilizers gives profitable returns they should be employed. Farm manures and clovers should likewise be used where possible.

Fertilizers are increasing in importance in Alberta. The use of suitable fertilizers not only tends to increase yields and hasten maturity but also assists in controlling weeds, plant diseases, insect damage, and in general helps to overcome the hazards of prairie farming. Under some conditions fertilizers materially increase the quality of crops.

Effect of Fertilizers on the Soil.

Sometimes the opinion is expressed that fertilizers impoverish the soil or affect it detrimentally. There is no basis for this opinion in the case of fertilizers commonly used. The only effect that the discontinuation of the use of commercial fertilizers will have on the crops is that the yield of the crop will drop to about the same level at which it would have been had the fertilizers never been applied.

Time of Application.

Fertilizers generally give best results for grain crops when applied at the time of seeding and drilled in with the seed. Early applications usually give better results than are obtained when the season is well advanced. For legumes and hays especially, early applications are to be preferred.

Method of Application.

Machinery is available either as a combination grain and fertilizer drill or as an attachment which can be used with any grain drill. The attachments are not expensive and will soon save their cost by a better distribution of fertilizer and saving of time as compared to broadcasting.

Drilling in the fertilizer with the grain crops is much to be preferred and should be used wherever possible. This distributes the fertilizer in a position where the young plants can have early access to it. It should be drilled with a combined grain and fertilizer drill or from an attachment rather than mixed with the grain in the ordinary grain drill, because in the latter case it is difficult to obtain an even distribution of the fertilizer, and if the grain is damp it may be damaged by the fertilizer. During seeding operations fertilizer left in the drill should be well protected from moisture, and at the end of the season all remaining fertilizer should be thoroughly removed from the machinery in order to prevent rusting.

Another method of spreading commercial fertilizers is to broadcast it by hand or with a cyclone seeder. It is possible to obtain a fairly even distribution of fertilizer with the cyclone seeder only when the fertilizer is grandular. When

broadcast, the rate of application should be somewhat heavier than when applied with the drill.

For hays it is desirable to apply the fertilizer with a drill, even on old stands. This gives more even distribution, and at the same time helps to place the fertilizer in the soil. Where a drill is not available the fertilizer may be broadcast. The fertilizer should be applied early in the spring.

For other crops, such as corn, beets, potatoes, peas, beans, and many other garden crops, it is preferable to drill the fertilizer near the seed row on each side at a depth equal to or slightly below the depth of the seed.

Rates of Application.

Rates will vary somewhat with different soil areas and for the different crops. In the dryer parts of the province the amount of fertilizer applied, and possibly the rate of seeding, should be reduced.

The following suggested rates are for the concentrated fertilizers. If low analysis fertilizers are used a heavier rate of application should be made. Possibly the rates should be compared in accordance with the differencs in analysis.

The following rates of application are based on experimentation and use of the more concentrated fertilizers during the past ten years in the Province of Alberta. These include ammonium phosphate (11-48), triple superphosphate, ammonium phosphate (16-20), and sulphate of ammonium. The low analysis fertilizers have only recently been introduced and at the moment sufficient data has not been made available to make it possible to give specific rates of application.

Dark Brown Soils

Grains (Wheat, Oats and Barley).

From 20 to 40 pounds per acre of ammonium phosphate (11-48) or triple superphosphate. If lower analysis fertilizers are used heavier rates of application are necessary.

Flax.

Very little experimental evidence is available, but it is suggested that flax requires a fertilizer that is fairly high in nitrogen, possibly 30 to 60 pounds per acre of ammonium phosphate (11-48) or ammonium phosphate (16-20).

Black Soils

Grains (Wheat, Oats and Barley).

From 30 to 50 pounds per acre of ammonium phosphate (11-48) or triple superphosphate.

Flax.

Very little experimental evidence is available, but it is suggested that flax requires a fertilizer that is fairly high in nitrogen, possibly 30 to 60 pounds per acre of ammonium phosphate (11-48) or ammonium phosphate (16-20).

Hays.

For clovers ammonium phosphate (16-20) at the rate of 40 to 60 pounds per acre, and for grasses ammonium sulphate or ammonium phosphate (16-20) at the rate of 40 to 60 pounds per acre.

Corn.

For forage production from 60 to 100 pounds per acre of ammonium phosphate (11-48) or ammonium phosphate (16-20).

For seed or table corn ammonium phosphate (11-48) is recommended, at the same rate.

Gray Wooded Soils

On the gray wooded soils nitrogen is the most essential element for the grains and grasses, whereas for the legumes sulphur is of first importance. It must be understood that the best results for fertilizers cannot be obtained on gray wooded soils unless clovers or alfalfa are included at fairly short intervals in the rotation.

Clovers and Alfalfa.

From 40 to 60 pounds per acre of ammonium sulphate or ammonium phosphate (16-20) if drilled, but a higher rate of application may be necessary in order to get an even distribution if the fertilizer is broadcast.

Grass Hays.

From 60 to 100 pounds per acre of ammonium sulphate.

Grains.

For the first crop after clovers 50 to 60 pounds per acre of ammonium phosphate (16-20). For all other grain crops 50 to 70 pounds per acre of ammonium sulphate.

Peats

Peats or muskegs are extremely variable and for this reason it is difficult to make a general statement regarding their fertilizer requirements. It is probable that much of our reclaimed peat land will eventually be seeded down to grasses and clovers, as this is the easiest way of handling such land. Some peats are very acid and should respond to treatment with lime. Where marl deposits rich in lime are conveniently

located, this material might be applied to a part of the muskeg at the rate of, say, one ton per acre, and its effect could then be observed. In experiments with commercial fertilizers on several areas a complete fertilizer containing nitrogen, phosphorus, and potassium has given the best results. It is fairly certain that in the long run, applications of manure or commercial fertilizers will be necessary to maintain satisfactory yields, but it is not certain that such applications will prove profitable for some years after peats have been brought under cultivation. Profitable increases of barley, oats, and hay have been obtained in certain cases from the application of a complete fertilizer, whereas in other cases no appreciable increases have been obtained. For example, a complete fertilizer produced an average yearly increase of 3.1 bushels of barley in 8 trials on 2 different areas, representing 3 seasons, and in 4 of these trials the increase was 5 or more bushels per acre. Also, during 5 seasons, the complete fertilizer produced an average increase of 686 pounds of dry barley hay in 15 trials on 3 different areas, and in 10 of these trials the increase was 800 pounds or more per acre. All fertilizers should be tested on a small scale, and if profitable should then be applied on a larger scale.

Fertilizers for Irrigated Lands

Up to the present time fertilizers containing phosphorus and nitrogen have been the ones showing greatest returns.

Alfalfa.

From 50 to 100 pounds per acre of ammonium phosphate (11-48) or triple superphosphate.

Grains (Wheat, Oats and Barley).

From 30 to 50 pounds per acre of ammonium phosphate (11-48) or triple superphosphate.

Beets.

From 80 to 100 pounds per acre of ammonium phosphate (11-48).

Corn, Peas and Beans.

From 50 to 100 pounds per acre of ammonium phosphate (11-48).

Date Due

MAR 0 1 RETURN			
MAR 8 RETURN			
APR 5 RETURN			
NOV 2 1 RETURN			
NOV 29 RETURN			
DUE CAN MAR 17 '79			
MAR 18 RETURN			
DUE CAN APR 18 '82			
APR 27 RETURN